

IAP20 Rec'd PCT/PTO 07 FEB 2006
手続補正書

(法第11条の規定による補正)

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4. 補正の対象 請求の範囲

5. 補正の内容 別紙の通り

・請求項2については、「請求項7又は9又は11」を「請求項7」に補正した。

・請求項3、請求項4については、請求項4の内容を請求項3に入れる。これより、請求項4を削除する。

・請求項 8 については、「 K_k 、 $\Sigma_{k+1|k}^{1/2}$ 」を「 $\Sigma_{k+1|k}^{1/2}$ 」に、「式 (2 1) と (2 2) を用いて」を「式 (2 1) を用いて」に補正した。

・請求項 8 については、 $\Sigma_{k|k-1}$ と C_k の両方の初期条件であるのでそのように明記した。また、「初期条件及びゲイン行列 K_k に基づき、」を「初期条件のもとで、」に補正した。

・請求項 10 については、明確になるよう「初期条件及びゲイン行列 K_k に基づき、」を「初期条件のもとで、」に補正した。

・請求項 14 については、 u_{k-i} を $u(k-i)$ に補正した。

6. 添付書類の目録

- (1) 請求の範囲 第 28、29、30、31、31/1、31/2、
 32、33、33/1、34、34/1、34/2、35、36、
 36/1、36/2、37、38、38/1、39、40、40/1 頁

1. (Canceled)

5 2. (Amended) The system estimation method according to claim 7 or 9 or 11, wherein the processing section calculates the existence condition in accordance with a following expression:

$$\hat{\Sigma}_{i|i}^{-1} = \hat{\Sigma}_{i|i-1}^{-1} + \frac{1 - \gamma_f^{-2}}{\rho} H_i^T H_i > 0, \quad i = 0, \dots, k \quad (17)$$

10 3. (Amended) The system estimation method according to claim 7 or 9 or 11, wherein the processing section calculates the existence condition in accordance with a following expression:

$$-\varrho \hat{\Xi}_i + \rho \gamma_f^2 > 0, \quad i = 0, \dots, k \quad (18)$$

here,

$$\varrho = 1 - \gamma_f^2, \quad \hat{\Xi}_i = \frac{\rho H_i K_{s,i}}{1 - H_i K_{s,i}}, \quad \rho = 1 - \chi(\gamma_f) \quad (19)$$

15 where the forgetting factor ρ and the upper limit value γ_f have a following relation:

$0 < \rho = 1 - \chi(\gamma_f) \leq 1$, where $\chi(\gamma_f)$ denotes a monotonically damping function of γ_f to satisfy $\chi(1) = 1$ and $\chi(\infty) = 0$.

4. (Canceled)

20 ~~(Amended) The system estimation method according to claim 7 or 9 or 11, wherein the forgetting coefficient ρ and the upper limit value γ_f have a following relation:~~

~~$0 < \rho = 1 - \chi(\gamma_f) \leq 1$, where $\chi(\gamma_f)$ denotes a monotone damping function of γ_f to satisfy $\chi(1) = 1$ and $\chi(\infty) = 0$.~~

25 5. (Canceled)

6. (Canceled)

7. ~~(Amended)~~—A system estimation method for making state
5 estimation robust and optimizing a forgetting factor ρ
simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$$x_{k+1} = F_k x_k + G_k w_k$$

$$y_k = H_k x_k + v_k$$

10 $z_k = H_k x_k$

here,

x_k : a state vector or simply a state,

w_k : a system noise,

v_k : an observation noise,

15 y_k : an observation signal,

z_k : an output signal,

F_k : dynamics of a system, and

G_k : a drive matrix,

as an evaluation criterion, a maximum value of an energy gain
20 which indicates a ratio of a filter error to a disturbance including
the system noise w_k and the observation noise v_k and is weighted
with the forgetting factor ρ is suppressed to be smaller than a
term corresponding to a previously given upper limit value γ_f , and
the system estimation method comprises:

25 a step at which a processing section inputs the upper limit
value γ_f , the observation signal y_k as an input of a filter and a
value including an observation matrix H_k from a storage section
or an input section;

a step at which the processing section determines the
30 forgetting factor ρ relevant to the state space model in accordance
with the upper limit value γ_f ;

a step of executing a hyper H_∞ filter at which the processing

section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix K_k and by following expressions (20) to (22), or, expression (20) and expressions which are deleted J_1^{-1} and J_1 in the expressions (21) and (22),:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k \hat{x}_{k-1|k-1}) \quad (20)$$

$$K_{s,k} = K_k(:, 1)/R_{e,k}(1, 1), \quad K_k = \rho^{\frac{1}{2}}(\rho^{-\frac{1}{2}}K_k R_{e,k}^{-\frac{1}{2}} J_1^{-1}) J_1 R_{e,k}^{\frac{1}{2}} \quad (21)$$

$$\left[\begin{array}{c|c} R_k^{\frac{1}{2}} & C_k \hat{\Sigma}_{k|k-1}^{\frac{1}{2}} \\ \hline 0 & \rho^{-\frac{1}{2}} \hat{\Sigma}_{k|k-1}^{\frac{1}{2}} \end{array} \right] \Theta(k) = \left[\begin{array}{c|c} R_{e,k}^{\frac{1}{2}} & 0 \\ \hline \rho^{-\frac{1}{2}} K_k R_{e,k}^{-\frac{1}{2}} J_1^{-1} & \hat{\Sigma}_{k+1|k}^{\frac{1}{2}} \end{array} \right] \quad (22)$$

Where,

$$\begin{aligned} R_k &= R_k^{\frac{1}{2}} J_1 R_k^{\frac{1}{2}}, \quad R_k^{\frac{1}{2}} = \begin{bmatrix} \rho^{\frac{1}{2}} & 0 \\ 0 & \rho^{\frac{1}{2}} \gamma_f \end{bmatrix}, \quad J_1 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}, \quad \hat{\Sigma}_{k|k-1} = \hat{\Sigma}_{k|k-1}^{\frac{1}{2}} \hat{\Sigma}_{k|k-1}^{\frac{1}{2}T} \\ R_{e,k} &= R_k + C_k \hat{\Sigma}_{k|k-1} C_k^T, \quad C_k = \begin{bmatrix} H_k \\ H_k \end{bmatrix}, \quad R_{e,k} = R_{e,k}^{\frac{1}{2}} J_1 R_{e,k}^{\frac{1}{2}T}, \quad \hat{x}_{0|0} = \hat{x}_0 \end{aligned} \quad (23)$$

$\Theta(k)$ denotes a J-unitary matrix, that is, satisfies $\Theta(k) J \Theta(k)^T = J$, $J = (J_1 \oplus I)$, I denotes a unit matrix, $K_k(:, 1)$ denotes a column vector of a first column of the matrix K_k ,

here,

10 $\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k ,

y_k : the observation signal,

F_k : the dynamics of the system,

$K_{s,k}$: the filter gain,

15 H_k : the observation matrix,

$\hat{\Sigma}_{k|k}$: corresponding to a covariance matrix of an error of $\hat{x}_{k|k}$,

$\Theta(k)$: the J-unitary matrix, and

$R_{e,k}$: an auxiliary variable.

a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;
20 a step at which the processing section calculates an existence

condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_1 or the observation matrix H_1 and the filter gain $K_{s,1}$, and

a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

8. (Amended) The system estimation method according to claim 7, wherein the step of executing the hyper H_∞ filter includes:

a step at which the processing section calculates K_k and $\hat{\Sigma}_{k+1|k}^{1/2}$ by using the expression (22);

a step at which the processing section calculates the filter gain $K_{s,k}$ based on an initial condition of $\hat{\Sigma}_{k|k-1}$ and an initial condition of C_k , and the matrix gain k_k by using the expressions (21) and (22);

a step at which the processing section updates a filter equation of the H_∞ filter of the expression (20); and

a step at which the processing section repeatedly executes the step of calculating by using the expression (22), the step of calculating by using the expressions (21) and (22), and, the step of updating while advancing the time k .

9. (Amended)—A system estimation method for making state estimation robust and optimizing a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$$x_{k+1} = F_k x_k + G_k w_k$$

$$y_k = H_k x_k + v_k$$

$$z_k = H_k x_k$$

here,

x_k : a state vector or simply a state,

w_k : a system noise,

v_k : an observation noise,

y_k : an observation signal,

5 z_k : an output signal,

F_k : dynamics of a system, and

G_k : a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including
10 the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f , and the system estimation method comprises:

a step at which a processing section inputs the upper limit
15 value γ_f , the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance
20 with the upper limit value γ_f ;

a step of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix
25 K_k and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k \hat{x}_{k-1|k-1}) \quad (61)$$

$$K_{s,k} = K_k(:, 1)/R_{e,k}(1, 1), \quad K_k = \rho^{\frac{1}{2}}(\bar{K}_k R_{e,k}^{-\frac{1}{2}})R_{e,k}^{\frac{1}{2}} \quad (62)$$

$$\begin{bmatrix} R_{e,k+1}^{\frac{1}{2}} & 0 \\ \left[\begin{array}{c} \bar{K}_{k+1} \\ 0 \end{array} \right] R_{e,k+1}^{-\frac{T}{2}} J_1 & \bar{L}_{k+1} R_{r,k+1}^{-\frac{T}{2}} \end{bmatrix} = \begin{bmatrix} R_{e,k}^{\frac{1}{2}} & \check{C}_{k+1} \bar{L}_k R_{r,k}^{-\frac{1}{2}} \\ \left[\begin{array}{c} 0 \\ \bar{K}_k \end{array} \right] R_{e,k}^{-\frac{1}{2}} J_1 & \rho^{-\frac{1}{2}} \bar{L}_k R_{r,k}^{-\frac{1}{2}} \end{bmatrix} \Theta(k) \quad (63)$$

here, $\Theta(k)$ denotes an arbitrary J-unitary matrix, and $C_k = C_{k+1}\Psi$ is established, where

$$\begin{aligned} R_k &= R_k^{\frac{1}{2}} J_1 R_k^{\frac{T}{2}}, \quad R_k^{\frac{1}{2}} = \begin{bmatrix} \rho^{\frac{1}{2}} & 0 \\ 0 & \rho^{\frac{1}{2}} \gamma_f \end{bmatrix}, \quad J_1 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}, \quad \hat{\Sigma}_{k|k-1} = \hat{\Sigma}_{k|k-1}^{\frac{1}{2}} \hat{\Sigma}_{k|k-1}^{\frac{T}{2}} \\ R_{e,k} &= R_k + C_k \hat{\Sigma}_{k|k-1} C_k^T, \quad C_k = \begin{bmatrix} H_k \\ H_k \end{bmatrix}, \quad R_{e,k} = R_{e,k}^{\frac{1}{2}} J_1 R_{e,k}^{\frac{T}{2}}, \quad \hat{x}_{0|0} = \hat{x}_0 \end{aligned} \quad (23)$$

here,

$\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k ,

5 y_k : the observation signal,

$K_{s,k}$: the filter gain,

H_k : the observation matrix,

$\Theta(k)$: the J-unitary matrix, and

$R_{e,k}$: an auxiliary variable.

10 a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_1 or the observation matrix

15 H_1 and the filter gain $K_{s,1}$, and

a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of
20 executing the hyper H_∞ filter.

10. (Amended) The system estimation method according to claim 9, wherein the step of executing the hyper H_∞ filter includes:

a step at which the processing section calculates K_k^- based on an initial condition of $R_{e,k+1}$, $R_{r,k+1}$ and L_{k+1}^- ~~and the matrix gain K_k^-~~ by using the expression (63);

5 a step at which the processing section calculates the filter gain $K_{s,k}$ based on the initial condition and by using the expression (62);

a step at which the processing section updates a filter equation of the H_∞ filter of the expression (61); and

10 a step at which the processing section repeatedly executes the step of calculating by using the expressions ~~(62) and (63)~~, the step of calculating by using the expression ~~(6261)~~, and, the step of updating while advancing the time k .

11. ~~(Amended)~~—A system estimation method for making state estimation robust and optimizing a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$$x_{k+1} = F_k x_k + G_k w_k$$

$$y_k = H_k x_k + v_k$$

20 $z_k = H_k x_k$

here,

x_k : a state vector or simply a state,

w_k : a system noise,

v_k : an observation noise,

25 y_k : an observation signal,

z_k : an output signal,

F_k : dynamics of a system, and

G_k : a drive matrix,

30 as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a

term corresponding to a previously given upper limit value γ_f , and the system estimation method comprises:

a step at which a processing section inputs the upper limit value γ_f , the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f ;

10 a step of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix K_k and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k \hat{x}_{k-1|k-1}) \quad (25)$$

$$K_{s,k} = \rho^{\frac{1}{2}} \bar{K}_k(:, 1) / R_{e,k}(1, 1) \quad (26)$$

$$\begin{bmatrix} \bar{K}_{k+1} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \bar{K}_k \end{bmatrix} - \rho^{-\frac{1}{2}} \tilde{L}_k R_{r,k}^{-1} \tilde{L}_k^T \check{C}_{k+1}^T \quad (27)$$

$$\tilde{L}_{k+1} = \rho^{-\frac{1}{2}} \tilde{L}_k - \begin{bmatrix} 0 \\ \bar{K}_k \end{bmatrix} R_{e,k}^{-1} \check{C}_{k+1} \tilde{L}_k \quad (28)$$

$$R_{e,k+1} = R_{e,k} - \check{C}_{k+1} \tilde{L}_k R_{r,k}^{-1} \tilde{L}_k^T \check{C}_{k+1}^T \quad (29)$$

$$R_{r,k+1} = R_{r,k} - \tilde{L}_k^T \check{C}_{k+1}^T R_{e,k}^{-1} \check{C}_{k+1} \tilde{L}_k \quad (30)$$

Where,

$$\check{C}_{k+1} = \begin{bmatrix} \check{H}_{k+1} \\ \check{H}_{k+1} \end{bmatrix}, \quad \check{H}_{k+1} = [u_{k+1} \ u(k+1-N)] = [u(k+1) \ u_k], \quad \check{H}_1 = [u(1), 0, \dots, 0]$$

$$R_{e,1} = R_1 + \check{C}_1 \check{\Sigma}_{1|0} \check{C}_1^T, \quad R_1 = \begin{bmatrix} \rho & 0 \\ 0 & -\rho \gamma_f^2 \end{bmatrix}, \quad \check{\Sigma}_{1|0} = \text{diag}\{\rho^2, \rho^3, \dots, \rho^{N+2}\}, \quad \rho = 1 - \chi(\gamma_f)$$

$$\tilde{L}_0 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \in \mathcal{R}^{(N+1) \times 2}, \quad R_{r,0} = \begin{bmatrix} -1 & 0 \\ 0 & \rho^{-N} \end{bmatrix}, \quad \bar{K}_0 = 0, \quad \hat{x}_{0|0} = \hat{x}_0, \quad \bar{K}_k = \rho^{-\frac{1}{2}} K_k \quad (31)$$

15

here,

y_k : the observation signal,

F_k : the dynamics of the system,

H_k : the observation matrix,

5 $\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k ,

$K_{s,k}$: the filter gain, obtained from the gain matrix K_k , and

$R_{e,k}$, L_k : an auxiliary variable.

a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

10 a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_1 or the observation matrix H_1 and the filter gain $K_{s,1}$, and

15 a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

20 12. (Canceled)

13. ~~{Amended}~~—The system estimation method according to claim 7 or 9 or 11, wherein an estimated value $z^v_{k|k}$ of the output signal is obtained from the state estimated value $\hat{x}_{k|k}$ at the time
25 k by a following expression:

$$z^v_{k|k} = H_k \hat{x}_{k|k}.$$

14. (Amended) The system estimation method according to claim 7 or 9 or 11, wherein the H_∞ filter equation is applied to
30 obtain the state estimated value $\hat{x}_{k|k} = [\hat{h}_1[k], \dots, \hat{h}_N[k]]^T$

a pseudo-echo is estimated by a following expression:

$$\hat{d}_k = \sum_{i=0}^{N-1} \hat{h}_i[k] u_{(k-i)}, \quad k = 0, 1, 2, \dots \quad (34)$$

and

an echo canceller is realized by canceling an actual echo
5 by the obtained pseudo-echo.

15. ~~(Amended)~~—A system estimation program for causing a
computer to make state estimation robust and to optimize a
forgetting factor ρ simultaneously in an estimation algorithm, in
10 which

for a state space model expressed by following expressions:

$$\mathbf{x}_{k+1} = \mathbf{F}_k \mathbf{x}_k + \mathbf{G}_k \mathbf{w}_k$$

$$\mathbf{y}_k = \mathbf{H}_k \mathbf{x}_k + \mathbf{v}_k$$

$$\mathbf{z}_k = \mathbf{H}_k \mathbf{x}_k$$

15 here,

\mathbf{x}_k : a state vector or simply a state,

\mathbf{w}_k : a system noise,

\mathbf{v}_k : an observation noise,

\mathbf{y}_k : an observation signal,

20 \mathbf{z}_k : an output signal,

\mathbf{F}_k : dynamics of a system, and

\mathbf{G}_k : a drive matrix,

as an evaluation criterion, a maximum value of an energy gain
which indicates a ratio of a filter error to a disturbance including
25 the system noise \mathbf{w}_k and the observation noise \mathbf{v}_k and is weighted
with the forgetting factor ρ is suppressed to be smaller than a
term corresponding to a previously given upper limit value γ_f , and

the system estimation program causes the computer to execute:

a step at which a processing section inputs the upper limit
30 value γ_f , the observation signal \mathbf{y}_k as an input of a filter and a

value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance
5 with the upper limit value γ_f ;

a step of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix
10 K_k and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k \hat{x}_{k-1|k-1}) \quad (25)$$

$$K_{s,k} = \rho^{\frac{1}{2}} \bar{K}_k(:, 1) / R_{e,k}(1, 1) \quad (26)$$

$$\begin{bmatrix} \bar{K}_{k+1} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \bar{K}_k \end{bmatrix} - \rho^{-\frac{1}{2}} \tilde{L}_k R_{r,k}^{-1} \tilde{L}_k^T \check{C}_{k+1}^T \quad (27)$$

$$\tilde{L}_{k+1} = \rho^{-\frac{1}{2}} \tilde{L}_k - \begin{bmatrix} 0 \\ \bar{K}_k \end{bmatrix} R_{e,k}^{-1} \check{C}_{k+1} \tilde{L}_k \quad (28)$$

$$R_{e,k+1} = R_{e,k} - \check{C}_{k+1} \tilde{L}_k R_{r,k}^{-1} \tilde{L}_k^T \check{C}_{k+1}^T \quad (29)$$

$$R_{r,k+1} = R_{r,k} - \tilde{L}_k^T \check{C}_{k+1}^T R_{e,k}^{-1} \check{C}_{k+1} \tilde{L}_k \quad (30)$$

Where,

$$\check{C}_{k+1} = \begin{bmatrix} \check{H}_{k+1} \\ \check{H}_{k+1} \end{bmatrix}, \quad \check{H}_{k+1} = [u_{k+1} \ u(k+1-N)] = [u(k+1) \ u_k], \quad \check{H}_1 = [u(1), 0, \dots, 0]$$

$$R_{e,1} = R_1 + \check{C}_1 \check{\Sigma}_{1|0} \check{C}_1^T, \quad R_1 = \begin{bmatrix} \rho & 0 \\ 0 & -\rho \gamma_f^2 \end{bmatrix}, \quad \check{\Sigma}_{1|0} = \text{diag}\{\rho^2, \rho^3, \dots, \rho^{N+2}\}, \quad \rho = 1 - \chi(\gamma_f)$$

$$\tilde{L}_0 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \in \mathcal{R}^{(N+1) \times 2}, \quad R_{r,0} = \begin{bmatrix} -1 & 0 \\ 0 & \rho^{-N} \end{bmatrix}, \quad \bar{K}_0 = 0, \quad \hat{x}_{0|0} = \bar{x}_0, \quad \bar{K}_k = \rho^{-\frac{1}{2}} K_k \quad (31)$$

here,

y_k : the observation signal,

F_k : the dynamics of the system,

15 H_k : the observation matrix,

$\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the

observation signals y_0 to y_k ,

$K_{s,k}$: the filter gain, obtained from the gain matrix K_k^- , and

$R_{e,k}$, L_k^- : an auxiliary variable.

a step at which the processing section stores an estimated

5 value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_1 or the observation matrix H_1 and the filter gain $K_{s,1}$, and

10 a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

15

16. ~~(Amended)~~—A computer readable recording medium recording a system estimation program for causing a computer to make state estimation robust and to optimize a forgetting factor ρ simultaneously in an estimation algorithm, in which

20 for a state space model expressed by following expressions:

$$x_{k+1} = F_k x_k + G_k w_k$$

$$y_k = H_k x_k + v_k$$

$$z_k = H_k x_k$$

here,

25 x_k : a state vector or simply a state,

w_k : a system noise,

v_k : an observation noise,

y_k : an observation signal,

z_k : an output signal,

30 F_k : dynamics of a system, and

G_k : a drive matrix,

as an evaluation criterion, a maximum value of an energy gain

which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f , and

5 the computer readable recording medium recording the system estimation program causes the computer to execute:

a step at which a processing section inputs the upper limit value γ_f , the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section
10 or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f ;

a step of executing a hyper H_∞ filter at which the processing
15 section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix K_k^- and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k \hat{x}_{k-1|k-1}) \quad (25)$$

$$K_{s,k} = \rho^{\frac{1}{2}} \bar{K}_k(:, 1) / R_{e,k}(1, 1) \quad (26)$$

$$\begin{bmatrix} \bar{K}_{k+1} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \bar{K}_k \end{bmatrix} - \rho^{-\frac{1}{2}} \tilde{L}_k R_{r,k}^{-1} \tilde{L}_k^T \check{C}_{k+1}^T \quad (27)$$

$$\tilde{L}_{k+1} = \rho^{-\frac{1}{2}} \tilde{L}_k - \begin{bmatrix} 0 \\ \bar{K}_k \end{bmatrix} R_{e,k}^{-1} \check{C}_{k+1} \tilde{L}_k \quad (28)$$

$$R_{e,k+1} = R_{e,k} - \check{C}_{k+1} \tilde{L}_k R_{r,k}^{-1} \tilde{L}_k^T \check{C}_{k+1}^T \quad (29)$$

$$R_{r,k+1} = R_{r,k} - \tilde{L}_k^T \check{C}_{k+1}^T R_{e,k}^{-1} \check{C}_{k+1} \tilde{L}_k \quad (30)$$

Where,

$$\check{C}_{k+1} = \begin{bmatrix} \check{H}_{k+1} \\ \check{H}_{k+1} \end{bmatrix}, \quad \check{H}_{k+1} = [u_{k+1} \ u(k+1-N)] = [u(k+1) \ u_k], \quad \check{H}_1 = [u(1), 0, \dots, 0]$$

$$R_{e,1} = R_1 + \check{C}_1 \check{\Sigma}_{1|0} \check{C}_1^T, \quad R_1 = \begin{bmatrix} \rho & 0 \\ 0 & -\rho \gamma_f^2 \end{bmatrix}, \quad \check{\Sigma}_{1|0} = \text{diag}\{\rho^2, \rho^3, \dots, \rho^{N+2}\}, \quad \rho = 1 - \chi(\gamma_f)$$

$$\tilde{L}_0 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \in \mathcal{R}^{(N+1) \times 2}, \quad R_{r,0} = \begin{bmatrix} -1 & 0 \\ 0 & \rho^{-N} \end{bmatrix}, \quad \bar{K}_0 = 0, \quad \hat{x}_{0|0} = \hat{x}_0, \quad \bar{K}_k = \rho^{-\frac{1}{2}} K_k \quad (31)$$

here,

y_k : the observation signal,

F_k : the dynamics of the system,

5 H_k : the observation matrix,

$\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k ,

$K_{s,k}$: the filter gain, obtained from the gain matrix K_k , and

$R_{e,k}$, \tilde{L}_k : an auxiliary variable.

10 a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_1 or the observation matrix

15 H_1 and the filter gain $K_{s,1}$, and

a step at which the processing section sets the upper limit

value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

5

17. (Amended)—A system estimation device for making state estimation robust and optimizing a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

10 $x_{k+1} = F_k x_k + G_k w_k$

$$y_k = H_k x_k + v_k$$

$$z_k = H_k x_k$$

here,

x_k : a state vector or simply a state,

15 w_k : a system noise,

v_k : an observation noise,

y_k : an observation signal,

z_k : an output signal,

F_k : dynamics of a system, and

20 G_k : a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a
25 term corresponding to a previously given upper limit value γ_f , and the system estimation device comprises:

a processing section to execute the estimation algorithm;
and

a storage section to which reading and/or writing is performed
30 by the processing section and which stores respective observed values, set values, and estimated values relevant to the state space model, wherein,

a means at which the processing section inputs the upper limit value γ_f , the observation signal y_k as an input of a filter and a value including an observation matrix H_k from the storage section or an input section;

5 a means at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f ;

a means of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix K_k and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k \hat{x}_{k-1|k-1}) \quad (25)$$

$$K_{s,k} = \rho^{\frac{1}{2}} \bar{K}_k(:, 1) / R_{e,k}(1, 1) \quad (26)$$

$$\begin{bmatrix} \bar{K}_{k+1} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \bar{K}_k \end{bmatrix} - \rho^{-\frac{1}{2}} \tilde{L}_k R_{r,k}^{-1} \tilde{L}_k^T \check{C}_{k+1}^T \quad (27)$$

$$\tilde{L}_{k+1} = \rho^{-\frac{1}{2}} \tilde{L}_k - \begin{bmatrix} 0 \\ \bar{K}_k \end{bmatrix} R_{e,k}^{-1} \check{C}_{k+1} \tilde{L}_k \quad (28)$$

$$R_{e,k+1} = R_{e,k} - \check{C}_{k+1} \tilde{L}_k R_{r,k}^{-1} \tilde{L}_k^T \check{C}_{k+1}^T \quad (29)$$

$$R_{r,k+1} = R_{r,k} - \tilde{L}_k^T \check{C}_{k+1}^T R_{e,k}^{-1} \check{C}_{k+1} \tilde{L}_k \quad (30)$$

Where,

$$\check{C}_{k+1} = \begin{bmatrix} \check{H}_{k+1} \\ \check{H}_{k+1} \end{bmatrix}, \quad \check{H}_{k+1} = [u_{k+1} \ u(k+1-N)] = [u(k+1) \ u_k], \quad \check{H}_1 = [u(1), 0, \dots, 0]$$

$$R_{e,1} = R_1 + \check{C}_1 \check{\Sigma}_{1|0} \check{C}_1^T, \quad R_1 = \begin{bmatrix} \rho & 0 \\ 0 & -\rho \gamma_f^2 \end{bmatrix}, \quad \check{\Sigma}_{1|0} = \text{diag}\{\rho^2, \rho^3, \dots, \rho^{N+2}\}, \quad \rho = 1 - \chi(\gamma_f)$$

$$\tilde{L}_0 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \in \mathcal{R}^{(N+1) \times 2}, \quad R_{r,0} = \begin{bmatrix} -1 & 0 \\ 0 & \rho^{-N} \end{bmatrix}, \quad \bar{K}_0 = 0, \quad \hat{x}_{0|0} = \hat{x}_0, \quad \bar{K}_k = \rho^{-\frac{1}{2}} K_k \quad (31)$$

here,

15 y_k : the observation signal,

F_k : the dynamics of the system,

H_k : the observation matrix,

$\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k ,

$K_{s,k}$: the filter gain, obtained from the gain matrix K_k^- , and

5 $R_{e,k}$, L_k^- : an auxiliary variable.

a means at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a means at which the processing section calculates an existence condition based on the upper limit value γ_f and the
10 forgetting factor ρ by the obtained observation matrix H_1 or the observation matrix H_1 and the filter gain $K_{s,1}$, and

a means at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section,
15 by decreasing the upper limit value γ_f and repeating the means of executing the hyper H_∞ filter.